DRIVING METHOD AND DRIVING CIRCUIT FOR COLOR LIQUID CRYSTAL DISPLAY

BACKGROUND OF THE INVENTION

Field of the Invention

The present invention relates to a driving method and a driving circuit for a color liquid crystal display and more particularly to the driving method and the driving circuit for driving the color liquid crystal display based on a gamma compensated video signal.

The present application claims the Convention Priority of Japanese Patent Application No. Hei11-316873 filed on November 8,1999, which is hereby incorporated by reference.

Description of the Related Art

Figure 19 is a block diagram showing a conventional electric configuration of a driving circuit of an analog circuit configuration of a color liquid crystal display 1.

The color liquid crystal display 1 is a liquid crystal display of an active matrix driving type using a TFT (Thin Film Transistor) as a switching element, in which intersection points of plural scanning electrodes (gate lines) provided at predetermined intervals in a row direction and plural data electrodes (source lines) provided at predetermined intervals in a column direction are used as pixels, for each pixel, a liquid cell of a equivalent capacitive load, a TFT for driving a

corresponding liquid crystal cell, a capacitor for keeping data charges during one vertical synchronous period are arranged, a data red signal, a data green signal and a data blue signal generated based on a video red signal S_R, a video green signal S_G, a video blue signal S_B, are applied to the data electrode and a scanning signal generated based on a horizontal synchronous signal S_H and a vertical synchronous signal S_V is applied to a scanning electrode, and then a color character, a color image and a like are displayed. In addition, the color liquid crystal display 1 is a normal white type having a high transmittance when no voltage is applied.

Further, the driving circuit of the color liquid crystal display 1 is mainly provided with clamp circuit 2_1 to clamp circuit 2_3, a reference voltage generating circuit 3, gamma compensating circuit 4_1 to gamma compensating circuit 4_3, polarity inverting circuit 5_1 to polarity inverting circuit 5_3, video amplifier 6_1 to video amplifier 6_3, a timing generating circuit 7, a data electrode driving circuit 8 and a scanning electrode driving circuit 9.

Clamp circuit 2_1 to clamp circuit 2_3 execute a clamp fixing (direct current refreshing) a level of a top or a back porch of the horizontal synchronous signal S_H of the video red signal S_R, the video green signal S_G and the video blue signal S_B supplied from outside to a black level and output a video red signal S_{RC}, a video green signal S_{GC} and a video blue signal S_{BC}.

The reference voltage generating circuit 3 a generates a reference voltage V_L, a reference voltage V_M, a reference voltage V_H used to gamma compensate the video red signal S_{RC}, the video green signal S_{GC} and the video blue signal S_{BC} and supplies the

video red signal S_{RC}, the video green signal S_{GC} and the video blue signal S_{BC} to gamma compensating circuit 4_1 to gamma compensating circuit 4_3. Gamma compensating circuit 4_1 to gamma compensating circuit 4_3, based on the reference voltage V_L, the reference voltage V_M and the reference voltage V_H supplied from the reference voltage generating circuit 3, give a gradient to the video red signal S_{RC}, the video green signal S_{GC} and the video blue signal S_{BC} by gamma compensating the video red signal S_{RC}, the video green signal S_{GC} and the video blue signal S_{BC} and output them as the video red light S_{RG}, the video green light S_{GG} and the video blue light S_{BG}.

Here, the gamma compensation will be explained. For example, when a logarithm value of a luminance originally provided for a subject such as a view and a person taken by a video camera is set to a horizontal axis and a logarithm value of a luminance of a reproduced image displayed on a display by a video signal from the video camera is set to a vertical axis and then an inclination angle of a reproducing characteristic curve is set to θ, tan θ is called a gamma (γ). When the luminance of the subject is reproduced on the display with fidelity, namely, when an input (horizontal axis) increases or decreases by one and also an output (vertical axis) increases or decreases by one, the inclination angle of the reproducing characteristic curve is a straight line having an inclination angle of 45°, tan45°=1 and then the gamma becomes 1. Therefore, in order to reproduce the luminance of the subject with fidelity, it is necessary to set a gamma of a whole system including taking the subject by the video camera though reproducing an image on the display to gamma=1.

However, an image pickup element such as CCD (Charge Coupled

Device), a CRT (Cathode Ray Tube) display or a like making up a video camera has a peculiar gamma. A gamma of the CCD is 1 and a gamma of the CRT display is about 2.2.

Therefore, it is necessary to compensate a video signal in order to obtain a reproduced image of good gradation by setting gamma=1 as a whole system, and this is called gamma compensation. Generally, the gamma compensation is applied to the video signal so as to be suitable to a gamma characteristic of the CRT display.

Polarity inverting circuit 5_1 to polarity inverting circuit 5_3, in order to alternately drive the color liquid crystal display 1, invert respective polarities of the video red light S_{RG}, the video green light S_{GG} and the video blue light S_{BG} and output them. Video amplifier 6_1 to video amplifier 6_3 amplify the video red light S_{RG}, the video green light S_{GG} and video blue light S_{BG} which are polarity-inverted to a level until the color liquid crystal display 1 can be driven. The timing generating circuit 7, based on the horizontal synchronous signal S_H and the vertical synchronous signal S_V supplied from outside, generates a horizontal scanning pulse P_H and a verticality scanning pulse P_V and supplies the horizontal scanning pulse P_H and the verticality scanning pulse P_V to the data electrode driving circuit 8 and the scanning electrode driving circuit 9. The data electrode driving circuit 8 generates a data red signal, a data green signal, a data blue signal from the video red light S_{RG}, the video green light S_{GG} and the video blue light S_{BG} which are amplified and polarity-inverted and applies the data red signal, the data green signal and the data blur signal to corresponding data electrodes in the color liquid crystal display 1 at a timing of the horizontal scanning pulse P_H supplied from the timing generating circuit 7.

The scanning electrode driving circuit 9 generates a scanning signal and supplies the scanning signal to a corresponding scanning electrode in the color liquid crystal display 1 at a timing of the vertical scanning pulse P_V supplied from the timing generating circuit 7.

Further, Fig. 20 is a block diagram showing a second conventional electric configuration of a driving circuit of a digital circuit configuration for the color liquid crystal display 1.

The driving circuit for the color liquid crystal display 1 is mainly provided with a controlling circuit 11, a gradation power supply circuit 12, a data electrode driving circuit 13 and a scanning electrode driving circuit 14.

The controlling circuit 11 is, for example, an ASIC (Application Specific Integrated Circuit), supplies red data D_R of six bits, green data D_G of six bits and blue data D_B of six bits supplied from outside to the data electrode driving circuit 13 and generates a horizontal scanning pulse P_H, a vertical scanning pulse P_V and a polarity inverting pulse POL for alternately driving the color liquid crystal display 1 and supplies them to the data electrode driving circuit 13 and the scanning electrode driving circuit 14. The gradation power supply circuit 12, as shown in Fig. 21, is provided with resistor 15_1 to resistor 15_{11} connected longitudinally between a reference voltage V_{REF} and ground and voltage follower 16_1 to voltage follower 16_9 connected with connection points of resistors adjacent to respective input terminals, and applies buffer to a gradation voltage V_0 to a gradation voltage V_9 set for the gamma compensation and appearing at connection points of adjacent resistors and

supplies gradation voltage V_0 to gradation voltage V_9 to the data electrode driving circuit 13.

The data electrode driving circuit 13, as shown in Fig. 21, is mainly provided with a multiplexer (MPX) 17, a DAC 18 and voltage follower 19_1 to voltage follower 19_{384}. In addition, a real data electrode driving circuit is provided with a shift register, a data register, a latch and a level shifter at a front step of the DAC 18, however, these elements and operations are not directly related with features of the present invention, therefore, explanations are omitted in this specification and they are not shown.

The multiplexer MPX 17 switches a group of gradation voltage V_0 to gradation voltage V_4 and a group of gradation voltage V_5 to gradation voltage V_9 among gradation voltage V_0 to gradation voltage V_9 supplied from the gradation power supply circuit 12, based on the polarity inverting pulse POL supplied from the controlling circuit 11 and supplies one of the groups to the DAC 18. The DAC 18 applies the gamma compensation to the red data D_R of six bits, the green data D_G of six bits and the blue data D_B of six bits supplied from the controlling circuit 11, converts the red data D_R, the green data D_G and the blue data D_B into an analog data red signal, an analog green signal and an analog blue signal and supplies the analog data red signal, the analog green signal and the analog blue signal to voltage follower 19_1 to voltage follower 19_{384}, based on the group of gradation voltage V_0 to gradation voltage V_4 and the group of gradation voltage V_5 to gradation voltage V_9. Voltage follower 19_1 to voltage follower 19_{384} apply buffer to the analog data red signal, the analog data green signal and the analog data blue signal supplied from the

DAC 18 and apply these data signals to corresponding data electrodes in the color liquid crystal display 1.

The scanning electrode driving circuit 14 sequentially generates scanning signals and sequentially applies the scanning signals to corresponding scanning electrodes in the color liquid crystal display 1 at a timing of the vertical scanning pulse P_V supplied from the timing generating circuit 7.

Now, in the driving circuit for the color liquid crystal display 1 of the first conventional example, the gamma compensation is applied to the video red signal S_{RC}, the video green signal S_{GC} and the video blue signal S_{BC} based on the common reference voltage V_L, the common reference voltage V_M, the common reference voltage V_H, so that the gamma characteristic of the CRT display (gamma is about 2.2) is suitable for the video red signal S_{RC}, the video green signal S_{GC} and the video blue signal S_{BC}.

Further, in the driving circuit for the color liquid crystal display 1 of the second conventional example, the gamma compensation is applied to the red data D_R, the green data D_G and the blue data D_B based on the common gradation reference voltage V_0 to the common reference voltage V_4 and common gradation reference voltage V_5 to common gamma reference voltage V_9 so that the gamma characteristic of the CRT display (gamma is about 2.2) is suitable for the red data D_R, the green data D_G and the blue data D_B.

However, a color liquid crystal display 1 has a gamma characteristic different from that of a CRT display, a characteristic curve of a transmittance T for an applied voltage V (a V-T characteristic curve) is not linear, and particularly, the transmittance hardly changes against a change of the applied

voltage near a black level. Further, since the V-T characteristic curve of the color liquid crystal display, as shown in Fig. 22, is different for each of a red (curve a), a green (curve b) and a blue (curve c), a characteristic curve of the luminance (an output) for the gradation (an input), as shown in Fig. 23, is different for each of the red (curve a), the green (curve b) and the blue (curve c). In Fig. 23, the luminance is a relative luminance in which the gamma compensation is applied to the video signal so as to be suitable to a gamma characteristic of a CRT display (about 2.2 gamma) in the gamma compensating circuit.

Accordingly, in the conventional gamma compensation common with the red, the green and the blue and making suitable to the gamma characteristic of the CRT display (about 2.2 gamma), for example, in a case of the V-T characteristic curve shown in Fig. 22, a transmittance is set to 100% when an applied voltage is 1.7 V, namely, a white level is set. However, particularly in the green (curve b), a white level is set at transmittance of 80%, therefore, it is impossible to carry out an optimal gamma compensation and then it is impossible to obtain a reproduced image of a good gradation. As a result, there a disadvantage in that it is impossible to meet a recent need of a high video quality.

Further, recently, in order to meet the need of the high video quality, a color liquid crystal display having a high transmittance is developed, and Fig. 24 shows an example of a V-T characteristic curve of a color liquid crystal display having such a high transmittance characteristic red (curve a), green (curve b), blue (curve c)). In such the V-T characteristic curve, each of red (curve a), green (curve b) and blue (curve c) has a transmittance of 100%, namely, each best luminance is too

different, therefore, there is a problem in that the color liquid crystal display 1 cannot be used since it is impossible to deal with gamma characteristics of the conventional gamma compensation which are used in common with red, green and blue.

Furthermore, as above described, in the first conventional example and the second conventional example of a driving circuit for the color liquid crystal display, gamma compensation is applied based on common reference voltage V_L, common reference voltage V_M and common reference voltage V_H or a common group of gradation voltage V_0 to gradation voltage V_4 and a common group of gradation voltage V_5 to gradation voltage V_9, therefore, there is a problem in that, though a gradation batter occurs in which gradation change is not displayed on a display as luminance changes, the gradation batter can not be removed.

SUMMARY OF THE INVENTION

In view of the above, it is an object of the present invention to provide a driving method and a driving circuit for a color liquid crystal display capable of carrying out a gamma compensation fully suitable to a characteristic of the color liquid crystal display and capable of removing a gradation batter though the gradation batter occurs in a specific color among red, green and blue.

According to a first aspect of the present invention, there is provided a driving method for a color liquid crystal display including:

a step of applying gamma compensations making suitable to a red transmittance characteristic, a green transmittance characteristic and a blue transmittance characteristic for an

applied voltage of the color liquid crystal display to a video red signal, a video green signal and a video blue signal independently in order to obtain a compensated video red signal, a compensated video green signal and a compensated blue signal; and

a step of driving the color liquid crystal display based on the compensated video red signal, the compensated video green signal and the compensated blue signal.

According to a second aspect of the present invention, there is provided a driving method for a color liquid crystal display including:

a step of applying gamma compensations, each of the gamma compensations including a first gamma compensation of voluntarily giving a luminance characteristic of a reproduced image to an input image luminance and a second gamma compensation of making suitable to a red transmittance characteristic, a green transmittance characteristic and a blue transmittance characteristic for an applied voltage of the color liquid crystal display to a video red signal, a video green signal and a video blue signal independently in order to obtain a compensated video red signal, a compensated video green signal and a compensated blue signal; and

a step of driving the color liquid crystal display based on the compensated video red signal, the compensated video green signal and the compensated blue signal.

In the foregoing, a preferable mode is one wherein the gamma compensations are applied using a common voltage or a common data to the video red signal, the video green signal and the video blue signal corresponding to an area in which the red transmittance

characteristic, the green transmittance characteristic and the blue transmittance characteristic for the applied voltage for the color liquid crystal display become an approximate similar characteristic curve.

Also, a preferable mode is one wherein voltages or data used for the gamma compensations are independently set in an area from a minimum transmittance to a maximum transmittance of each of the red transmittance characteristic, the green transmittance characteristic and the blue transmittance characteristic for the applied voltage for the color liquid crystal display.

Furthermore, a preferable mode is one wherein the voltages or the data are independently changeable.

According to a third aspect of the present invention, there is provided a driving circuit for a color liquid crystal display including:

a first gamma compensating circuit for applying a gamma compensation of compensating a video red signal so as to be suitable to a red transmittance characteristic for an applied voltage in the color liquid crystal display and for outputting a compensated video red signal;

a second gamma compensating circuit for applying a gamma compensation of compensating a video green signal so as to be suitable to a green transmittance characteristic in the applied voltage of the color liquid crystal display and for outputting a compensated video green signal;

a third gamma compensating circuit for applying a gamma compensation of compensating a video blue signal so as to be suitable to a blue transmittance characteristic for the applied voltage of the color liquid crystal display and for outputting

a compensated video blue signal;

a reference voltage generating circuit for supplying respectively reference voltages to the first gamma compensating circuit, the second gamma compensating circuit and the third gamma compensating circuit; and

a data electrode driving circuit for driving corresponding electrodes of the color liquid crystal display based on the compensated video red signal, the compensated green signal and the compensated video blue signal.

According to a fourth aspect of the present invention, there is provided a driving circuit for a color liquid crystal display including:

a first gamma compensating circuit for applying a gamma compensation to a video red signal, the gamma compensation including a first gamma compensation of voluntarily giving a luminance characteristic of a reproduced image for an input image luminance and a second gamma compensation of compensating the video red signal so as to be suitable to a red transmittance characteristic for an applied voltage in the color liquid crystal display and for outputting a compensated video red signal;

a second gamma compensating circuit for applying a gamma compensation to a video green signal, the gamma compensation including a first gamma compensation of voluntarily giving a luminance characteristic of a reproduced image for an input image luminance and a second gamma compensation of compensating the video green signal so as to be suitable to a green transmittance characteristic for an applied voltage of the color liquid crystal display and for outputting a compensated video green signal;

a third gamma compensating circuit for applying a gamma

compensation to a video blue signal, the gamma compensation including a first gamma compensation of voluntarily giving a luminance characteristic of a reproduced image for an input image luminance and a second gamma compensation of compensating the video blue signal so as to be suitable to a blue transmittance characteristic for an applied voltage of the color liquid crystal display and for outputting a compensated video blue signal;

a reference voltage generating circuit for supplying respective reference voltages to the first gamma compensating circuit, the second gamma compensating circuit and the third gamma compensating circuit; and

a data electrode driving circuit for driving corresponding electrodes in the color liquid crystal display based on the compensated video red signal, the compensated video green signal and the compensated video blue signal.

In the forgoing, a preferable mode is one wherein the reference voltage generating circuit supplies a common reference voltage to the video red signal, the video green signal and the video blue signal corresponding to an area in which the red transmittance characteristic, the green transmittance characteristic and the blue transmittance characteristic for the applied voltage in the color liquid crystal display become an approximate similar characteristic curve.

Also, a preferable mode is one wherein the reference voltages are independently set for each area from a minimum transmittance to a maximum transmittance in each of the red transmittance characteristic, the green transmittance characteristic and the blue transmittance characteristic for the applied voltage for the color liquid crystal display.

Furthermore, a preferable mode is one wherein the reference voltages are independently changeable.

According to a fifth aspect of the present invention, there is provided a driving circuit for a color liquid crystal display including:

a gradation power supply circuit for generating a plurality of red gradation voltages, a plurality of green gradation voltages and a plurality of blue gradation voltages used for independently applying a gamma compensation to a video red signal, a video green signal and a video blue signal in order to compensate the video red signal, the video green signal and the video blue signal so as to be suitable to a red transmittance characteristic, a green transmittance characteristic and a blue transmittance characteristic for an applied voltage in the color liquid crystal display; and

a data electrode driving circuit for applying a data red signal, a data green signal and a data blue signal obtained by applying the gamma compensation to a red data, a green data and a blue data and by analog-converting the red data, the green data and the blue data based on the plurality of red gradation voltages, the plurality of green gradation voltages and the plurality of blue gradation voltages to corresponding data electrodes of the color liquid crystal display.

According to a sixth aspect of the present invention, there is provided a driving circuit for a color liquid crystal display including:

a gradation power supply circuit for generating a plurality of red gradation voltages, a plurality of green gradation voltages and a plurality of blue gradation voltages used for independently

applying a gamma compensation to a video red signal, a video green signal and a video blue signal, the gamma compensation including a first gamma compensation of voluntarily giving a luminance characteristic of a reproduced image for an input image luminance and a second gamma compensation of compensating the video blue signal so as to be suitable to a blue transmittance characteristic for an applied voltage of the color liquid crystal display; and

a data electrode driving circuit for applying a data red signal, a data green signal and a data blue signal obtained by applying a gamma compensation to a red data, a green data and a blue data and by analog-converting the red data, the green data and the blue data based the plurality of red gradation voltages, the plurality of green gradation voltages and the plurality of blue gradation voltages to corresponding data electrodes of the color liquid crystal display.

In the forgoing, a preferable mode is one wherein the gradation power supply circuit generates a common gradation voltage to the video red signal, the video green signal and the video blue signal corresponding to an area in which the red transmittance characteristic, the green transmittance characteristic and the blue transmittance characteristic for the applied voltage for the color liquid crystal display become an approximate similar characteristic curve.

Also, a preferable mode is one wherein the plurality of red gradation voltages, the plurality of green gradation voltages and the plurality of blue gradation voltages are independently set for each area from a minimum transmittance to a maximum transmittance in each of the red transmittance characteristic, the green transmittance characteristic and the blue transmittance

characteristic in the applied voltage in the color liquid crystal display.

Furthermore, a preferable mode is one wherein the plurality of red gradation voltages, the plurality of green gradation voltages and the plurality of blue gradation voltages are independently changeable.

According to a seventh aspect of the present invention, there is provided a driving circuit for a color liquid crystal display including:

a first gamma compensating section for applying a gamma compensation to a digital video red signal, the gamma compensation including a first gamma compensation of voluntarily giving a luminance characteristic of a reproduced image for an input image luminance and a second gamma compensation of compensating the digital video red signal so as to be suitable to a red transmittance characteristic for an applied voltage of the color liquid crystal display and for outputting a compensated digital video red signal;

a second gamma compensating section for applying a gamma compensation to a digital video green signal, the gamma compensation including a first gamma compensation of voluntarily giving a luminance characteristic of a reproduced image for an input image luminance and a second gamma compensation of compensating the digital video green signal so as to be suitable to a green transmittance characteristic for an applied voltage in the color liquid crystal display and for outputting a compensated digital video green signal;

a third gamma compensating section for applying a gamma compensation to a digital video blue signal, the gamma compensation including a first gamma compensation of voluntarily

giving a luminance characteristic of a reproduced image for an input image luminance and a second gamma compensation of compensating the digital video blue signal so as to be suitable to a blue transmittance characteristic for an applied voltage of the color liquid crystal display and for outputting a compensated digital video blue signal; and

a data electrode driving circuit for applying a data red signal, a data green signal and a data blue signal obtained by analog-converting a compensated red data, a compensated green data and a compensated blue data to corresponding electrodes of the color liquid crystal display.

According to an eighth aspect of the present invention, there is provided a driving circuit for a color liquid crystal display including:

a first gamma compensating section for applying a gamma compensation to a digital video red signal, the gamma compensation including a first gamma compensation of voluntarily giving a luminance characteristic of a reproduced image for an input image luminance and a second gamma compensation of compensating a video red signal so as to be suitable to a red transmittance characteristic for an applied voltage of the color liquid crystal display, the second gamma compensation including a second gamma slight compensation of executing a compensation caused by a difference among a red characteristic, a green characteristic and a blue characteristic and for outputting a compensated video red signal;

a second gamma compensating section for applying a gamma compensation to a digital video green signal, the gamma compensation including a first gamma compensation of voluntarily

giving a luminance characteristic of a reproduced image for an input image luminance and a second gamma compensation of compensating the video green signal to be suitable to a green transmittance characteristic for an applied voltage of the color liquid crystal display, the second gamma compensation including a second gamma slight compensation of executing a compensation caused by a difference among the red characteristic, the green characteristic and the blue characteristic and for outputting a compensated video green signal;

a third gamma compensating section for applying a gamma compensation to a digital video blue signal, the gamma compensation including a first gamma compensation of voluntarily giving a luminance characteristic of a reproduced image for an input image luminance and a second gamma compensation of compensating the video blue signal to be suitable to a blue transmittance characteristic for an applied voltage of the color liquid crystal display, the second gamma compensation including a second gamma slight compensation of executing a compensation caused by a difference among the red characteristic, the green characteristic and the blue characteristic and for outputting a compensated video blue signal;

a gradation power supply circuit for generating a plurality of red gradation voltages, a plurality of green gradation voltages and a plurality of blue gradation voltages used to apply a second gamma rough compensation caused by a similarity among the red characteristic, the green characteristic and the blue characteristic to compensated red data, compensated green data and compensated blue data included in the second gamma compensation making suitable to the red transmittance

characteristic, the green transmittance characteristic and the blue transmittance characteristic for an applied voltage of the color liquid crystal display; and

a data electrode driving circuit for applying a data red signal, a data green signal and a data blue signal obtained by applying the gamma rough compensation to the compensated red data, the compensated green data and the compensated blue data and by analog-converting the compensated red data, the compensated green data and the blue data based on the plurality of red gradation voltages, the plurality of green gradation voltages and the plurality of blue gradation voltages to corresponding electrodes of the color liquid crystal display.

In the forgoing, a preferable mode is one wherein the first gamma compensating section, the second gamma compensating section and the third gamma compensating section apply the gamma compensation to the red data, the green data and the blue data by operation processes.

Also, a preferable mode is one wherein the first gamma compensating section, the second gamma compensating section and the third gamma compensating section previously hold the compensated red data, the compensated green data and the compensated blue data which are results of the gamma compensation corresponding to the red data, the green data and the blue data and the compensated red data, the compensated green data and the compensated blue data are read using the red data, the green data and the blue data as reference addresses so as to be corresponded in order to apply the gamma compensation.

Furthermore, a preferable mode is one wherein the first gamma compensating section, the second gamma compensating section

and the third gamma compensating section independently apply the gamma compensation in each area from a minimum transmittance to a maximum transmittance of each of a red transmittance characteristic, a green transmittance characteristic and a blue transmittance characteristic for the applied voltage of the color liquid crystal display.

With the above configurations, it is possible to carry out an optimal gamma compensation fully suitable to a characteristic of a color liquid crystal display. Also, though a gradation batter occurs in a specific color among red, green and blue, it is possible to remove the gradation batter.

Also, since the color liquid crystal display is driven based on the compensated video red signal, the compensated video green signal and the compensated video blue signal obtained by independently applying gamma compensations to the video red signal, the video green signal and the video blue signal so as to be suitable to the red transmittance characteristic, the green transmittance characteristic and the blue transmittance characteristic for an applied voltage to the color liquid crystal display, it is possible to carry out an optimal gamma compensation fully suitable to a characteristic of the color liquid crystal display. Thus, it is possible to fully meet a recent need of a high quality image. Also, it is possible to use a color liquid crystal display having a high transmittance characteristic in which maximum luminance are very different concerning red, green and blue. Furthermore, though the gradation batter occurs in a specific color among red, green and blue, a voltage for the gamma compensation concerning the specific color can be changed, therefore, it is possible to remove the gradation batter of the

specific color.

Also, using the common voltage or the common data, the gamma compensation can be applied to the video red signal, the video green signal and the video blue signal corresponding to an area in which characteristic curves become an approximately similar form in the red transmittance characteristic, the green transmittance characteristic and blue transmittance characteristic, therefore, it is possible to reduce a circuit scale.

Further, the first gamma compensating section, the second gamma compensating section and the third gamma compensating section previously memorize the compensated red data, the compensated green data and the compensated blue data corresponding red data, green data and blue data, read the corresponding compensated red data, the corresponding compensated green data and the corresponding compensated blue data using the red data, the green data. And then, the first gamma compensating section, the second gamma compensating section and the third gamma compensating section apply the blue data as reference addresses and the gamma compensation, it is possible to execute the gamma compensation at higher speed.

BRIEF DESCRIPTION OF THE DRAWINGS

The above and other objects, advantages, and features of the present invention will be more apparent from the following description taken in conjunction with the accompanying drawings in which:

Fig. 1 is a block diagram showing an electrical configuration

of a driving circuit for a color liquid crystal display according a first embodiment of the present invention;

Fig. 2 is a schematic circuit diagram showing an example of an electrical configuration of a gamma compensating circuit in the driving circuit for the color liquid crystal display of the first embodiment;

Fig. 3 is a block diagram showing an example of an electrical configuration of a reference voltage generating circuit in the driving circuit for the color liquid display of the first embodiment;

Fig. 4 is a schematic circuit diagram showing an example of an electrical configuration of an adder in the reference voltage generating circuit of the first embodiment;

Fig. 5 is a graph showing an example of a relationship between a reference voltage V_{LR}, a reference voltage V_{MR} and a reference voltage V_{HR} used for applying gamma compensation to a video red signal S_{RC} and a compensated video red signal S_{RG} to which gamma compensation is applied in the first embodiment;

Fig. 6 is a block diagram showing an electrical configuration of a driving circuit for a color liquid crystal display according a second embodiment of the present invention;

Fig. 7 is a block diagram showing an example of an electrical configuration of a reference voltage generating circuit in the driving circuit for the color liquid crystal display of the second embodiment;

Fig. 8 is a block diagram showing an electrical configuration of a driving circuit for a color liquid crystal display according a third embodiment of the present invention;

Fig. 9 is a block diagram showing an example of an electrical

configuration of a gradation power supply circuit and a data electrode driving circuit for the liquid crystal display in the driving circuit of the third embodiment;

Fig. 10 is a graph showing an example of a relationship between red data of eight bits supplied to a DAC in the data electrode driving circuit and red gradation voltage V_{R0} 2 to red gradation voltage V_{R8} and red gradation voltage V_{R9} to red gradation voltage V_{R17} in the third embodiment;

Fig. 11 is a block diagram showing an electrical configuration of a driving circuit for a color liquid crystal display according a fourth embodiment of the present invention;

Fig. 12 is a block diagram showing an electrical configuration of a controlling circuit, a gradation power supply circuit and a data electrode driving circuit for the color liquid crystal display in the driving circuit of the fourth embodiment;

Fig. 13 is a graph showing an example of a relationship between compensated red data D_{RG} of eight bits, compensated green data D_{GG} of eight bits and compensated blue data D_{BG} of eight bits supplied to a DAC in the data electrode driving circuit and gradation voltage V_0 to gradation voltage V_8 and gradation voltage V_9 to gradation voltage V_{17} in the fourth embodiment;

Fig. 14 is a block diagram showing an electrical configuration of a driving circuit for a color liquid crystal display according a fifth embodiment of the present invention;

Fig. 15 is a block diagram showing an electrical configuration of a controlling circuit and a data electrode driving circuit in the driving circuit for the color liquid crystal display of the fifth embodiment;

Fig. 16 is a graph showing a relationship between red data

D_R of eight bits and compensated red data D_{RG} of ten bits memorized in a ROM in the controlling circuit of the fifth embodiment;

Fig. 17 is a graph showing an example of a relationship between compensated red data D_{RG} of ten bits, compensated green data D_{GG} of ten bits and compensated blue data D_{BG} of ten bits supplied to a DAC in the data electrode driving circuit and gradation voltage V_0 to gradation voltage V_8 and gradation voltage V_9 to gradation voltage V_{17} in the fifth embodiment;

Fig. 18 is a graph showing an example of a relation between red data D_R of eight bits supplied to a DAC in a data electrode driving circuit in a driving circuit for a color liquid crystal display and red gradation voltage V_{R0} to red gradation voltage V_{R8} and red gradation voltage V_{R9} to red gradation voltage V_{R17} in a modification of the third embodiment;

Fig. 19 a block diagram showing a first conventional example of an electrical configuration of a driving circuit for a color liquid crystal display;

Fig. 20 a block diagram showing a second conventional example of an electrical configuration of a driving circuit for a color liquid crystal display;

Fig. 21 is a schematic block diagram showing an electrical configuration of a gradation power supply circuit and a data electrode driving circuit in the driving circuit for the conventional color liquid crystal display;

Fig. 22 is a graph showing an example of a V-T characteristic curve in the conventional color liquid crystal display;

Fig. 23 is a graph showing an example of a gamma characteristic curve in the conventional color liquid crystal display; and

Fig. 24 is a graph showing another example of a V-T characteristic curve in the conventional color liquid crystal display.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

Best modes for carrying out the present invention will be described in further detail using various embodiments with reference to the accompanying drawings.

First Embodiment

Figure 1 is a block diagram showing an electrical configuration of a driving circuit of an analog circuit configuration for a color liquid crystal display 1 according to a first embodiment of the present invention. In Fig. 1, the color liquid crystal display 1 is a liquid crystal display of an active matrix driving type using a TFT (Thin Film Transistor) as a switching element.

The driving circuit of the color liquid crystal display 1 is mainly provided with clamp circuit 2_1 to clamp circuit 2_3, a reference voltage generating circuit 22, gamma compensating circuit 21_1 to gamma compensating circuit 21_3, polarity inverting circuit 5_1 to polarity inverting circuit 5_3, video amplifier 6_1 to video amplifier 6_3, a timing generating circuit 7, a data electrode driving circuit 8 and a scanning electrode driving circuit 9. That is, the reference voltage generating circuit 22, and gamma compensating circuit 21_1 to gamma compensating circuit 21_3 are provided instead of the reference voltage generating

circuit 3, and gamma compensating circuit 4_1 to gamma compensating circuit 4_3 in a conventional example shown in Fig. 19.

~~Gamma compensating circuit 21_1 to gamma compensating circuit 21_3, based a reference voltage V_{LR}, a reference voltage V_{MR}, a reference voltage V_{HR}, a reference voltage V_{LG}, a reference voltage V_{MG}, a reference voltage V_{HG}, a reference voltage V_{LB}, a reference voltage V_{MB} and a reference voltage V_{HB} supplied from the reference voltage generating circuit 22, apply gamma compensation to the video red signal S_{RC}, the video green signal S_{GC} and the video blue signal S_{BC} independently in order to give gradients to them and then output the video red signal S_{RG}, the video green signal S_{GG} and the video blue signal S_{BG}. In addition, it is assumed that the gamma compensation in the first embodiment includes a gamma compensation (hereunder, called a first gamma compensation) for giving a luminance characteristic of a reproduced image for a luminance of an input image voluntarily and a gamma compensation (hereunder, called a second gamma compensation) suitable to each of a red V-T characteristic, a green V-T characteristic and a blue V-T characteristic in the color liquid crystal display 1.~~

Sub B1

Here, Fig. 2 shows an example of an electric configuration of the gamma compensating circuit 21_1. The gamma compensating circuit 21_1 is mainly provided with differential circuit 23_1 to differential circuit 23_3, a voltage follower 24 and a resistor 25.

The differential circuit 23_1 is mainly provided with a transistor Q1 in which the video red signal S_{RC} is applied to a base, a setting voltage V_{GC} is applied to a collector through the resistor 25 and the collector is connected to each collector of a transistor Q3 and a transistor Q5 and an emitter is connected

to a constant current source I1 through a resistor R1 and a transistor Q2 in which the reference voltage V_{LR} is applied to a base, a power supply voltage V_{CC} is applied to a collector, an emitter is connected to the constant current source I1 through a resistor R2. Similarly, a differential circuit 23_3 is mainly provided with the transistor Q5 in which the video red signal S_{RC} is applied to a base, the setting voltage V_{GC} is applied to a collector through the resistor 25 and the collector is connected to each collector of the transistor Q1 and the transistor Q3 and an emitter is connected to a constant current source I3 through a resistor R3 and a transistor Q4 in which the reference voltage V_{MR} is applied to a base, the power supply voltage the V_{CC} is applied to a collector, an emitter is connected to the constant current source I2 through a resistor R4. Similarly, a differential circuit 23_2 is mainly provided with the transistor Q3 in which the video red signal S_{RC} is applied to a base, the setting voltage V_{GC} is applied to a collector through the resistor 25 and the collector is connected to each collector of the transistor Q1 and the transistor Q5 and an emitter is connected to a constant current source I3 through a resistor R5 and the transistor Q6 in which the reference voltage V_{HR} is applied to a base, the power supply voltage the V_{CC} is applied to a collector, an emitter is connected to the constant current source I3 through a resistor R6. Further, each of the collectors of the transistor Q1, the transistor Q3 and the transistor Q5 is connected to an input terminal of the voltage follower 24. The voltage follower 24 applies buffer to the video red signal S_{RC} which is gamma compensated and outputs it.

The reference voltage generating circuit 22 (Fig. 1), based

on a control signal S_{C1}, a control signal S_{C2}, a control signal S_{C3} and a reference voltage change data D_{RV} supplied from a CPU (Central Processing Unit) not shown, generates the reference voltage V_{LR}, the reference voltage V_{MR}, the reference voltage V_{HR}, the reference voltage V_{LG}, the reference voltage V_{MG}, the reference voltage V_{HG}, the reference voltage V_{LB}, the reference voltage V_{MB} and the reference voltage V_{HB} used for gamma compensating the video red signal S_{RC}, the video green signal S_{GC} and the video blue signal S_{BC} and supplies these reference voltages to gamma compensating circuit 21_1 to gamma compensating circuit 21_3.

Next, Fig. 3 is an example of an electric configuration of the reference voltage generating circuit 22. The reference voltage generating circuit 22 is mainly provided with a DAC 25, a reference voltage supply source 26, adder 27_1 to adder 27_9 and switch 28_1 to switch 28_9.

The DAC 25 converts the reference voltage change data D_{RV} supplied from the CPU (not shown) into analog change voltage V_1 to analog voltage V_9 and then respectively supplies analog change voltage V_1 to analog change voltage V_9 to each of first input terminals of adder 27_1 to adder 27_9. The reference voltage supply source 26 is configured by connecting in parallel a pair of a resistor R11 and a resistor R12 lengthwise connected, a pair of a resistor R13 and a resistor R14 lengthwise connected, a pair of a resistor R15 and a resistor R16 lengthwise connected, a pair of a resistor R17 and a resistor R18 lengthwise connected, a pair of a resistor R19 and a resistor R20 lengthwise connected, a pair of a resistor R21 and a resistor 22 lengthwise connected, a pair of a resistor R23 and a resistor R24 lengthwise connected, a pair of a resistor R25 and a resistor R26 lengthwise connected, and

a pair of a resistor R27 and a resistor R28 lengthwise connected and by inserting these pairs between the reference voltage V_{REF} and ground. Nine voltages generating at connection points of nine pairs of resistors in parallel are respectively supplied to second input terminals of the adder 27_1 through the 27_9 as a fixed reference voltage V_{LRF}, a fixed reference voltage V_{MRF}, a fixed reference voltage V_{HRF}, a fixed reference voltage V_{LGF}, a fixed reference voltage V_{MGF}, a fixed reference voltage V_{HGF}, a fixed reference voltage V_{LBF}, a fixed reference voltage V_{MBF}, a fixed reference voltage V_{HBF} and are respectively applied to first selection terminals Ta of switch 28_1 to switch 28_9.

Adder 27_1 to adder 27_9 respectively add the analog change voltage V_1 to analog change voltage V_9 supplied from the corresponding first input terminals Ta to the fixed reference voltage V_{LRF}, the fixed reference voltage V_{MRF}, the fixed reference voltage V_{HRF}, the fixed reference voltage V_{LGF}, the fixed reference voltage V_{MGF}, the fixed reference voltage V_{HGF}, the fixed reference voltage V_{LBF}, to the fixed reference voltage V_{MBF}, and the fixed reference voltage V_{HBF} and respectively apply an addition result $(V_{LRF}+V_1)$, an addition result $(V_{MRF}+V_2)$, an addition result $(V_{HRF}+V_3)$, an addition result $(V_{LGF}+V_4)$, an addition result $(V_{MGF}+V_5)$, an addition result $(V_{HGF}+V_6)$, an addition result $(V_{LBF}+V_7)$, an addition result $(V_{MBF}+V_8)$ and an addition result $(V_{HBF}+V_9)$ (which are not shown) to second selection terminals Tb of switch 28_1 to switch 28_9 so as to be corresponded.

Next, Fig. 4 shows an example of an electrical configuration of the adder 27_1. The adder 27_1 is manly provided with a variable resistor VR1, resistor R31 to resistor R36 having a same resistance value and an operational amplifier OP. In addition,

adder 27_2 to adder 27_9 are approximately similar to the adder 27_1 concerning the electrical configuration and operation except that supplied fixed reference voltage and change voltage are different, therefore, explanations thereof will be omitted.

Each of switch 28_1 to switch 28_9 is switched from a common terminal Tc to the first selection terminal Ta or the selection terminal Tb based on a control signal S_{c1}, a control signal S_{c2} or a control signal S_{c3} supplied from the CPU (not shown) and supply the fixed reference voltage V_{LRF}, the fixed reference voltage V_{MRF}, the fixed reference voltage V_{HRF}, the fixed reference voltage V_{LGF}, the fixed reference voltage V_{MGF}, the fixed reference voltage V_{HGF}, the fixed reference voltage V_{LBF}, the fixed reference voltage V_{MBF} and the fixed reference voltage V_{HBF} or the addition result $(V_{LRF}+V_1)$, the addition result $(V_{MRF}+V_2)$, the addition result $(V_{HRF}+V_3)$, the addition result $(V_{LGF}+V_4)$, the addition result $(V_{MGF}+V_5)$, the addition result $(V_{HGF}+V_6)$, the addition result $(V_{LBF}+V_7)$, the addition result $(V_{MBF}+V_8)$ and the addition result $(V_{HBF}+V_9)$ which are not shown, as the reference voltage V_{LR}, the reference voltage V_{MR}, the reference voltage V_{HR}, the reference voltage V_{LG}, the reference voltage V_{MG}, the reference voltage V_{HG}, the reference voltage V_{LB}, the reference voltage V_{MB} and the reference voltage V_{HB} to gamma compensating circuit 21_1 to gamma compensating circuit 21_3.

Next, explanations will be given of operations of gamma compensating circuit 21_1 to gamma compensating circuit 21_3 and the reference voltage generating reference circuit 22 which has features of the present invention in operations of the above-mentioned driving circuit for the color liquid crystal display 1 with reference to Fig. 5.

Figure 5 is a graph showing an example of a relationship between the reference voltage V_{LR}, the reference voltage V_{MR} and the reference voltage V_{HR} used to apply the gamma compensation to the video red signal S_{RG} and a gamma compensated video red signal S_{RC}. First, the reference voltage V_{LR} is set near a minimum voltage value (a black level) of the video red signal S_{RC}, the reference voltage V_{HR} is set near a maximum voltage value (a white level) of the video red signal S_{RC} and the reference voltage V_{MR} is set at a half-tone (gray) of the video red signal S_{RC}. In particular, concerning the reference voltage V_{HR}, for example, when the color liquid crystal display 1 has a V-T characteristic shown in Fig. 22 (curve a), the reference voltage V_{HR} is set to 1.0V so as to obtain a maximum transmittance T (maximum luminance) instead of 1.7V of the conventional voltage, and, for example, when the color liquid crystal display 1 has a V-T characteristic shown in Fig. 24 (curve a), the reference voltage VHR is set to 1.0V so as to obtain a maximum transmittance T (maximum luminance).

~~In addition, the reference voltage V_{LG}, the reference voltage V_{MG} and the reference voltage V_{HG} for applying the gamma compensation to the video green signal S_{GC} and the reference voltage V_{LB}, the reference voltage V_{MB} and the reference voltage V_{HB} for applying the gamma compensation to the video green signal S_{BC} are set so that an area from a minimum luminance (a minimum transmittance) to a maximum transmittance of a corresponding V-T characteristic can be fully used. In other words, for example, when the color liquid crystal display 1 has the V-T characteristic as shown in Fig. 22 (curve b), the reference voltage V_{LG} is set to approximate 1.0V in order to obtain a maximum transmittance (a maximum luminance) instead of approximate 1.7V of the~~

~~conventional voltage, and when the color liquid crystal display 1 has a V-T characteristic as shown in Fig. 24 (curve b), the reference voltage V_{LG} is set to approximate 1.8V in order to obtain a maximum transmittance (a maximum luminance, a peak point). Similarly, for example, when the color liquid crystal display 1 has a V-T characteristic to shown in Fig. 22 (curve c), the reference voltage V_{LB} is set to approximate 1.5V in order to obtain a maximum transmittance (a maximum luminance) instead of approximate 1.7V of the conventional voltage, and when the color liquid crystal display 1 has a V-T characteristic to shown in Fig. 24 (curve c), the reference voltage V_{LB} is set to approximate 2.0V in order to obtain a maximum transmittance (a maximum luminance, a peak point).~~

In brief, the first embodiment is characterized in that each difference among a red V-T characteristic, a green V-T characteristic and a blue V-T characteristic in the color liquid crystal display 1 is considered and the reference voltage V_{LR}, the reference voltage V_{MR}, the reference voltage V_{HR}, the reference voltage V_{LG}, the reference voltage V_{MG}, the reference voltage V_{HG}, the reference voltage V_{LB}, the reference voltage V_{MB} and the reference voltage V_{HB} are set so that a range from a maximum luminance to a minimum luminance of each V-T characteristic can be fully used.

Next, for example, when a non-active control signal S_{C1} is supplied from the CPU (not shown), the common terminals Tc of the first switch 28_1 to switch 28_3 shown in Fig. 3 are connected to the fixed reference voltage selection terminals Ta, therefore, the fixed reference voltage V_{LRF}, the fixed reference voltage V_{MRF} and the fixed reference voltage V_{HRF} supplied from the reference voltage supply source 26

are directly supplied to the gamma compensating circuit 21_1 shown in Fig. 1 as the reference voltage V_{LR}, the reference voltage V_{MR} and the reference voltage V_{HR}. With this operation, the gamma compensation including the first gamma compensation and the second gamma compensation is applied to the video red signal S_{RC} based on the reference voltage V_{LR}, the reference voltage V_{MR} and the reference voltage V_{HR} in the gamma compensating circuit 21_1 independently of the video green signal S_{GC} and the video blue signal S_{BC}, and thereby a gradient is given. Then, the video red signal S_{RC} is output as a video red signal S_{RG}.

In addition, please refer to Japanese Patent Application Laid-open No. Hei 6-205340 disclosing details of the operation of the gamma compensating circuit 21_1.

Similarly, for example, when a non-active control signal S_{C2} is supplied from the CPU (not shown), the common terminals Tc of the first switch 28_4 to switch 28_6 shown in Fig. 3 are connected to the first selection terminals Ta, therefore, the fixed reference voltage V_{LGF}, the fixed reference voltage V_{MGF} and the fixed reference voltage V_{HGF} supplied from the reference voltage supply source 26 are directly supplied to the gamma compensating circuit 21_2 shown in Fig. 1 as the reference voltage V_{LG}, the reference voltage V_{MG} and the reference voltage V_{HG}. With this operation, the gamma compensation including the first gamma compensation and the second gamma compensation is applied to the video red signal SG_C based on the reference voltage V_{LG}, the reference voltage V_{MG} and the reference voltage V_{HG} in the gamma compensating circuit 21_2 independently of the video red signal S_{RC} and the video blue signal S_{BC}, and thereby a gradient is given. Then, the video green signal S_{GC} is output as a video green signal S_{GG}.

NSC27

Similarly, for example, when a non-active control signal S_{c3} is supplied from the CPU (not shown), the common terminals Tc of switch 28_7 to switch 28_9 shown in Fig. 3 are connected to the first selection terminal Ta, therefore, the fixed reference voltage V_{LBF}, the fixed reference voltage V_{MBF} and the fixed reference voltage V_{HBF} supplied from the reference voltage supply source 26 are directly supplied to the gamma compensating circuit 21_3 shown in Fig. 1 as the reference voltage V_{LB}, the reference voltage V_{MB} and the reference voltage V_{HB}. With this operation, the gamma compensation including the first gamma compensation and the second gamma compensation is applied to the video blue signal S_{BC} based on the reference voltage V_{LB}, the reference voltage V_{MB} and the reference voltage V_{HB} in the gamma compensating circuit 21_3 independently of the video red signal S_{RC} and the video green signal S_{GC}, and thereby a gradient is given. Then, the video blue signal S_{BC} is output as a video blue signal S_{BG}.

As another case, for example, when an active control signal S_{c1} and a reference voltage change data D_{RV} are supplied from the CPU (not shown), the DAC 25 converts the reference voltage change data D_{RV} into analog change voltage V_1 to analog change voltage V_9 and supplies to respective input terminal of adder 27_1 to adder 27_9. With this operation, each of adder 27_1 to adder 27_3 adds each of the fixed reference voltage V_{LRF}, the fixed reference voltage V_{MRF}, the fixed reference voltage V_{HRF} supplied to the corresponding first input terminal to each of change voltage V_1 to change voltage V_3 supplied to the corresponding second input terminal and applies each of the addition result $(V_{LRF}+V_1)$, the addition result $(V_{MRF}+V_2)$ and the addition result $(V_{HRF}+V_3)$, to each of the second selection terminals Tb of switch 28_1 to switch 28_3. Further, since the common

terminal Tc of switch 28_1 to switch 28_3 are connected to the second selection terminal Tb, the addition result $(V_{LRF}+V_1)$, the addition result $(V_{MRF}+V_2)$ and the addition result $(V_{HRF}+V_3)$ are supplied to the gamma compensating circuit 21_1 as the reference voltage V_{LR}, the reference voltage V_{MR} and the reference voltage V_{HR}. With this operation, the gamma compensation including the first gamma compensation and the second gamma compensation is applied to the video red signal S_{RC} in the gamma compensating circuit 21_1 based on the reference voltage V_{LR}, the reference voltage V_{MR}, the reference voltage V_{HR} which are finely adjusted in order to change a change quantity (incline) of a voltage level of the video red signal S_{RG} for the reference voltage V_{LR}, the reference voltage V_{MR} and the reference voltage V_{HR} independently of the video green signal S_{GC} and the video blue signal S_{BC}, and thereby a gradient is given. Then, the video red signal S_{RC} is output as a video red signal S_{RG}.

INS C3

Similarly, for example, when an active control signal S_{C2} and a reference voltage change data D_{RV} are supplied from the CPU (not shown), the DAC 25 converts the reference voltage change data D_{RV} into analog change voltage V_1 to analog change voltage V_9 and supplies them to respective input terminals of adder 27_1 to adder 27_9. With this operation, each of adder 27_4 to adder 27_6 adds each of the fixed reference voltage V_{LGF}, the fixed reference voltage V_{MGF} and the fixed reference voltage V_{HGF} supplied to the corresponding first input terminal to each of change voltage V_4 to change voltage V_6 supplied to the corresponding second input terminal and applies each of the addition result $(V_{LGF}+V_4)$, the addition result $(V_{MGF}+V_5)$ and the addition result $(V_{HGF}+V_6)$ to each of the second selection terminals Tb of switch 28_4 to switch 28_6.

Further, since the common terminals Tc of switch 28_4 to switch 28_6 are connected to the second selection terminal Tb, the addition result $(V_{LGF}+V_4)$, the addition result $(V_{MGF}+V_5)$ and the addition result $(V_{HGF}+V_6)$ are supplied to the gamma compensating circuit 21_2 as the reference voltage V_{LG}, the reference voltage V_{MG} and the reference voltage V_{HG}. With this operation, the gamma compensation including the first gamma compensation and the second gamma compensation is applied to the video green signal S_{GC} in the gamma compensating circuit 21_2 based on the reference voltage V_{LG}, the reference voltage V_{MG} are the reference voltage V_{HG} which are finely adjusted in order to a change quantity (incline) of a voltage level of the video red signal S_{RG} to the reference voltage V_{LG}, the reference voltage V_{MG} and the reference voltage V_{HG} independently of the video red signal S_{RC} and the video blue signal S_{BC}, and thereby a gradient is given. Then, the video green signal S_{GC} is output as a video green signal S_{GG}.

Sub C3

Similarly, for example, when an active control signal S_{C3} and a reference voltage change data D_{RV} are supplied from the CPU (not shown), the DAC 25 converts the reference voltage change data D_{RV} into analog change voltage V_1 to analog change voltage V_9 and supplies to respective input terminals of adder 27_1 to adder 27_9. With this operation, each of adder 27_7 to adder 27_9 adds each of the fixed reference voltage V_{LBF}, the fixed reference voltage V_{MBF} and the fixed reference voltage V_{HBF} supplied to the corresponding first input terminal to each of change voltage V_7 to change voltage V_9 supplied to the corresponding second input terminal and applies each of the addition result $(V_{LBF}+V_7)$, the addition result $(V_{MBF}+V_8)$ and the addition result $(V_{HBF}+V_9)$, each of the second selection terminals Tb of switch 28_7 to switch 28_9. Further, since the common

terminals Tc of switch 28_7 to switch 28_9 are connected to the second selection terminals Tb, the addition result $(V_{LBF}+V_7)$, the addition result $(V_{MBF}+V_8)$ and the addition result $(V_{HBF}+V_9)$ are supplied to the gamma compensating circuit 21_3 as the reference voltage V_{LB}, the reference voltage V_{MB} and the reference voltage V_{HB}. With this operation, the gamma compensation including the first gamma compensation and the second gamma compensation is applied to the video blue signal S_{BC} in the gamma compensating circuit 21_3 based on the reference voltage V_{LB}, the reference voltage V_{MB} and the reference voltage V_{HB} which are finely adjusted in order to change a change quantity (incline) of a voltage level of the video red signal S_{RG} to the reference voltage V_{LG}, the reference voltage V_{MB} and the reference voltage V_{HB} independently of the video red signal S_{RC} and the video green signal S_{GC}, and thereby a gradient is given. Then, the video blue signal S_{BC} is output as a video blue signal S_{BG}.

As above described, in the first embodiment, in gamma compensating circuit 21_1 to gamma compensating circuit 21_3, each range from a maximum luminance to a minimum luminance of each of the red V-T characteristic, the green V-T characteristic and the blue V-T characteristic in the color liquid crystal display 1 are fully considered, the gamma compensation is independently applied to the video red signal S_{RC}, the video green signal SR_{GC} and the video blue signal S_{BC} based on the reference voltage V_{LR}, the reference voltage V_{MR}, the reference voltage V_{HR}, the reference voltage V_{LG}, the reference voltage V_{MG}, the reference voltage V_{HG}, the reference voltage V_{LB}, the reference voltage V_{MB} and the reference voltage V_{HB} which are fixed or finely adjusted, and a gradient is given. Accordingly, an optimal gamma compensation can

be carried out and a reproduced image of a good gradation can be obtained. As a result, it is possible to meet a recent request of a high quality image. Furthermore, it is fully available to the color liquid crystal display 1 having a V-T characteristic of a high transmittance shown in Fig. 24.

In addition, when a gradation batter occurs in a specific color among red, green and blue, the CPU (not shown) supplies reference voltage change data for changing reference voltage (any one of the reference voltage V_L, the reference voltage V_M and the reference voltage V_H) corresponding to a color range in which the gradation batter occurs (near the white level, near gray or near the black level) and the active control signal S_{C1} to the reference voltage generating circuit 22, and thereby this gradation batter can be removed.

Second Embodiment

Next, explanations will be given of the second embodiment according to the present invention.

Figure 6 is a block diagram showing an electrical configuration of a driving circuit for the color liquid crystal display 1 according to the second embodiment of the present invention. In Fig. 6, same numerals are given to corresponding parts in Fig. 1 and the explanations thereof are omitted. In the driving circuit for the color liquid crystal display 1 shown in Fig. 6, instead of the reference voltage generating circuit 22 shown in Fig. 1, a reference voltage generating circuit 31 is provided.

Figure 7 is a block diagram showing one example of an

electrical configuration of the reference voltage generating circuit 31. In Fig. 7, same numerals are given to corresponding parts in Fig. 3 and the explanations thereof are omitted. In the reference voltage generating circuit 31 shown in Fig. 7, instead of the DAC 25 and the reference voltage supply source 26 shown in Fig. 3, a DAC 32 and a reference voltage supply source 33 are provided.

The DAC 32 converts a reference voltage change data D_{RV} supplied from a CPU (not shown) into an analog change voltage V_1, an analog change voltage V_2, an analog change voltage V_3, an analog change voltage V_5, an analog change voltage V_6, an analog change voltage V_8 and an analog change voltage V_9 and supplies them to respective first input terminals of an adder 27_1, an adder 27_2, an adder 27_3, an adder 27_5, an adder 27_6, an adder 27_8 and an adder 27_9. In the reference voltage supply source 33, an resistor R17 and an resistor R18 lengthwise connected and an resistor R23 and an resistor R24 lengthwise connected are removed from the reference voltage supply source 26 shown in Fig. 3. Seven voltages generating at connection points of seven pairs of resistors lengthwise connected are respectively supplied to second input terminals of the adder 27_1, the adder 27_2, the adder 27_3, the adder 27_5, the adder 27_6, the adder 27_8 and the adder 27_9 as a fixed reference voltage V_{LF}, a fixed reference voltage V_{MRF}, a fixed reference voltage V_{HRF}, a fixed reference voltage V_{MGF}, a fixed reference voltage V_{HGF}, a fixed reference voltage V_{MBF}, a fixed reference voltage V_{HBF} and are applied to respective first selection terminals Ta of a switch 28_1, a switch 28_2, a switch 28_3, a switch 28_5, a switch 28_6, a switch 28_8 and a switch 28_9.

Further, in the reference voltage generating circuit 31

shown in Fig. 7, an adder 27_4 and an adder 27_7 and an switch 28_4 and an switch 28_7 shown in Fig. 3 are removed, and a control signal S_{C4} is supplied from the CPU (not shown) to the switch 28_1.

Next, in the second embodiment, reasons are given of the above-mentioned configuration. As understood from Fig. 22 and Fig. 24, there are differences in a range in which a transmittance T is high concerning each of a red V-T characteristics, a green V-T characteristic and a blue V-T characteristic in the color liquid crystal display 1, however, there is little difference in a range in which the transmittance T is low. So, in the second embodiment, in order to reduce a circuit scale, as gamma compensation for the video red signal S_{RC}, gamma compensation for the video green signal S_{GC} and gamma compensation for the video blue signal S_{BC} corresponding to the range in which the transmittance T is low, a similar gamma compensation is applied to the video red signal S_{RC}, the video green signal S_{GC} and the video blue signal S_{BC} using a common reference voltage V_L. In addition, it is assumed that gamma compensation in the second embodiment includes a first gamma compensation and a second gamma compensation.

Further, operations are similar to those of the first embodiment except the gamma compensation using the common reference voltage V_L, therefore, explanations thereof are omitted.

As above described, according to the second embodiment, in the range in which there is no difference of the V-T characteristic and the transmittance T is low, the gamma compensation is applied using the common reference voltage V_L in order to give a gradient, therefore, a circuit scale can be reduced in addition to effects obtained from the configuration according to the first

embodiment.

Third Embodiment

Next, explanations will be given of the third embodiment of the present invention.

Figure 8 is a block diagram showing an electrical configuration of a driving circuit of a digital circuit configuration for a color liquid crystal display 1 according to the third embodiment of the present invention. In Fig. 8, same numerals are given to corresponding parts in Fig. 20 and the explanations thereof are omitted.

In the driving circuit for the color liquid crystal display 1 shown in Fig. 8, instead of a controlling circuit 11, a gradation power supply circuit 12 and a data electrode driving circuit 13 shown in Fig. 20, a controlling circuit 41, a gradation power supply circuit 42 and a data electrode driving circuit 43 are provided.

The controlling circuit 41 is, for example, an ASIC, and supplies red data D_R of eight bits, green data D_G of eight bits, blue data D_B of eight bits supplied from outside to the data electrode driving circuit 43 and generates a polarity inverting pulse POL for alternately driving a horizontal scanning pulse P_H, a vertical scanning pulse P_V and the color liquid crystal display 1 to supply the polarity inverting pulse POL to the data electrode driving circuit 43 and a scanning electrode driving circuit 14. Further, the controlling circuit 41 independently applies gamma compensation to the red data D_R, the green data D_G and the blue data D_B, and thereby supplies red gradation voltage data D_{GR}, green

gradation voltage data D_{GG} and blue gradation voltage data D_{GB} to the gradation power supply circuit 42. In addition, it is assumed that the gamma compensation in the third embodiment includes a first gamma compensation and a second gamma compensation.

The gradation power supply circuit 42, as shown in Fig. 9, is mainly provided with a DAC 44_1, a DAC 44_2 and a DAC 44_3 and voltage follower 45_1 to voltage follower 45_{54}. The DAC 44_1 converts the red gradation voltage data D_{GR} supplied from the controlling circuit 41 into analog red gradation voltage V_{R0} to analog red gradation voltage V_{R17} and supplies them to voltage follower 45_1 to voltage follower 45_{18}. Similarly, the DAC 44_2 converts the green gradation voltage data D_{GG} supplied from the controlling circuit 41 into analog green gradation voltage V_{G0} to analog green gradation voltage V_{G17} and supplies them to voltage follower 45_{19} to voltage follower 45_{36}. The DAC 44_3 converts the blue gradation voltage data D_{GB} supplied from the controlling circuit 41 into analog blue gradation voltage V_{B0} to analog blue gradation voltage V_{B17} and supplies them to voltage follower 45_{37} to voltage follower 45_{54}. Voltage follower 45_1 to voltage follower 45_{54} applies buffer to red gradation voltage V_{R0} to red gradation voltage V_{R17}, green gradation voltage V_{G0} to green gradation voltage V_{G17} and blue gradation voltage V_{B0} to blue gradation voltage V_{B17} for the gamma compensation and supplies them to the data electrode driving circuit 43.

The data electrode drive circuit 43, as shown in Fig. 9, is mainly provided with a MPX 46_1, a MPX 46_2 and a MPX 46_3, a DAC 47_1 of eight bits, a DAC 47_2 of eight bits and a DAC 47_3 of eight bits and voltage follower 48_1 to voltage follower 48_{384}. In addition, in a real data electrode driving circuit, a shift register, a data

register, a latch, a level shifter and a like are provided at a front step of a DAC, however, there is no relationship between features of the present invention and these elements and operations, therefore, explanations thereof are omitted.

INSC4 The MPX 46_1 switches a group of red gradation voltage V_{R0} to red gradation voltage V_{R8} over a group of red gradation voltage V_{R9} to red gradation voltage V_{R17} in red gradation voltage V_{R0} to red gradation voltage V_{R17} supplied from the gradation power supply circuit 42 based on the polarity inverting pulse POL supplied from the controlling circuit 41 and supplies any one of the groups to the DAC 47_1. Similarly, the MPX 46_2 switches a group of green gradation voltage V_{G0} to green gradation voltage V_{G8} over a group of red gradation voltage V_{G9} to red gradation voltage V_{G17} in red gradation voltage V_{G0} to red gradation voltage V_{G17} supplied from the gradation power supply circuit 42 based on the polarity inverting pulse POL supplied from the controlling circuit 41 and supplies any one of the groups to the DAC 47_2. The MPX 46_3 switches a group of blue gradation voltage V_{B0} to blue gradation voltage V_{B8} over a group of blue gradation voltage V_{B9} to the blue gradation voltage V_{B17} in blue gradation voltage V_{B0} to blue gradation voltage V_{B17} supplied from the gradation power supply circuit 42 based on the polarity inverting pulse POL supplied from the controlling circuit 41 and supplies any one of the groups to the DAC 47_3.

The DAC 47_1, based on the group of red gradation voltage V_{R0} to red gradation voltage V_{R8} or the group of red gradation voltage V_{R9} to red gradation voltage V_{R17}, applies the gamma compensation to the red data D_R of eight bits supplied from the controlling circuit 41 so as to give a gradient to the red data D_R, converts the red data D_R into an analog data red signal and then supplies

the analog data red signal to voltage follower 48_1 to voltage follower 48_{382}. Here, Fig. 10 shows an example of a relationship between the red data D_R (indicated by hexadecimal number (HEX)) of eight bits supplied to the DAC 47_1 and red gradation voltage V_{R0} to red gradation voltage V_{R8} or red gradation voltage V_{R9} to red gradation voltage V_{R17}. As understood from Fig. 10, in order to apply the gamma compensation including the first gamma compensation and the second gamma compensation to the red data D_R so as to give a gradient to the red data D_R, the group of red gradation voltage V_{R0} to the red gradation voltage V_{R8} or the group of red gradation voltage V_{R9} to red gradation voltage V_{R17} which has a nonlinear voltage value is supplied to the DAC 47_1.

Similarly, The DAC 47_2, based on the group of green gradation voltage V_{G0} to green gradation voltage V_{G8} or the group of green gradation voltage V_{G9} to green gradation voltage V_{G17}, applies the gamma compensation to the green data D_G of eight bits supplied from the controlling circuit 41 so as to give a gradient to the green data D_G, converts the green data D_G into an analog data green signal and then supplies the analog data green signal to voltage follower 48_{129} to voltage follower 48_{256}. Not shown, however, in order to apply the gamma compensation including the first gamma compensation and the second gamma compensation to the green data D_G so as to give a gradient to the red data D_G, the group of green gradation voltage V_{G0} to green gradation voltage V_{G8} or the group of green gradation voltage V_{G9} to green gradation voltage VG_{G17} which has a nonlinear voltage value is supplied to the DAC 47_2.

Similarly, The DAC 47_3, based on the group of blue gradation voltage V_{B0} to blue gradation voltage V_{B8} or the group of blue gradation voltage V_{B9} to blue gradation voltage V_{B17}, applies the

gamma compensation to the blue data D_B of eight bits supplied from the controlling circuit 41 so as to give gradient to the blue data D_B, converts the blue data D_B into an analog data blue signal and then supplies the analog data blue signal to voltage follower 48_{257} to voltage follower 48_{384}. Not shown, however, in order to apply the gamma compensation including the first gamma compensation and the second gamma compensation to the blue data D_B so as to give a gradient to the blue data D_B, the group of blue gradation voltage V_{B0} to blue gradation voltage V_{B8} or the group of blue gradation voltage V_{B9} to blue gradation voltage VG_{B17} which has a nonlinear voltage value is supplied to the DAC 47_3.

Voltage follower 48_1 to voltage follower 48_{384} apply buffer to the data red signal, the data green signal and the data blue signal supplied from DAC 47_1 to DAC 47_3 and apply these signals to corresponding data electrodes of the color liquid crystal display 1.

Next, explanations will be given of operations of the controlling circuit 41, the gradation power supply circuit 42 and the data electrode driving circuit 43 which are features of the the present invention in operations of the driving circuit for the liquid crystal display 1.

First, the controlling circuit 41 supplies the red data DR of eight bits, the green data D_G of eight bits and the blue data D_B of eight bits supplied from the outside to the data electrode driving circuit 43 and supplies the red gradation voltage data D_{GR}, the green gradation voltage data D_{GG} and the blue gradation voltage data D_{GB} which are considered in order to fully use a range of the V-T characteristic from the minimum luminance to maximum luminance for each of red, green and blue in the color liquid

crystal display 1 to the gradation power supply circuit 42. The gradation power supply circuit 42 analog-converts the red gradation voltage data D_{GR}, the green gradation voltage data D_{GG} and the blue gradation voltage data D_{GB}, and then applies buffer to these data and supplies them to the data electrode driving circuit 43 as red gradation voltage V_{R0} to red gradation voltage V_{R17}, green gradation voltage V_{G0} to green gradation voltage V_{G17} and blue gradation voltage V_{B0} to blue gradation voltage V_{B17}.

Accordingly, the data electrode driving circuit 43, based on the group of red gradation voltage V_{R0} to red gradation voltage V_{R8} or the group of red gradation voltage V_{R9} to red gradation voltage V_{R17}, the group of green gradation voltage V_{G0} to the green gradation voltage V_{G8} or the group of green gradation voltage V_{G9} to green gradation voltage V_{G17} and the group of blue gradation voltage V_{B0} to blue gradation voltage V_{B8} or the group of blue gradation voltage V_{B9} to blue gradation voltage V_{B17}, applies the gamma compensation to the red data D_R of eight bits, the green data D_G of eight bits and the blue data D_B of eight bits so as to give gradient to these data and analog-converts the data red signal, the data green signal and the data blue signal and then applies these signals to the corresponding data electrodes in the color liquid crystal display 1 after applying buffer.

As above described, according to the third embodiment, approximately similar effects of the first embodiment can be obtained, that is, in digital circuit configuration, it is possible to give a gradient by applying an optimal gamma compensation, to obtain a reproduced image of fine gradation and to use the color liquid crystal display 1 fully even if it has a V-T characteristic of a high transmittance.

Further, when a gradation batter occurs in a specific color among red, green and blue, the controlling circuit 41 supplies the gradation voltage data D_G changed in order to change a gradation voltage (any one of the gradation voltage V_0 to the gradation voltage V_{17}) corresponding to a color area in which the gradation batter occurs (any one of near white level, near gray and near black level) to the gradation power supply circuit 42, and thereby the gradation batter can be removed.

Fourth Embodiment

Next, explanations will be given of the fourth embodiment of the present invention.

Figure 11 is a block diagram showing an electrical configuration of a driving circuit of a digital circuit configuration for the color liquid crystal display 1 according to the fourth embodiment of the present invention. In Fig. 11, same numerals are given to corresponding parts in Fig. 8 and the explanations thereof are omitted. The driving circuit for the color liquid crystal display shown 1 in Fig. 11 is provided with a controlling circuit 51, a gradation power supply circuit 52 and the data electrode driving circuit 53 instead of the controlling circuit 41, the gradation power supply circuit 42 and the data electrode driving circuit 43 in Fig. 8.

The controlling circuit 51, for example, is an ASIC, and , as shown in Fig. 12, is mainly provided with a controlling section 54 and gamma compensating section 55_1 to gamma compensating section 55_3. The controlling section 54 generates a horizontal scanning pulse P_H, a vertical scanning pulse P_V and a polarity

inverting pulse POL for alternatively driving the color liquid crystal display 1 and supplies them to the data electrode driving circuit 53 and a scanning electrode driving circuit 14 and supplies a control signal S_{CR}, a control signal S_{CG} and a control signal S_{CB} for controlling gamma compensating section 55_1 to gamma compensating section 55_3. The gamma compensating section 55_1 to gamma compensating section 55_3 applies the gamma compensation independently to red data D_R, green data D_G and blue data D_B supplied from the outside by operational processes based on the control signal S_{CR}, the control signal S_{CG} and the control signal S_{CB} supplied from the controlling section 54 and gives a gradient to these data, and then respective compensation results are supplied to the data electrode driving circuit 53 as a compensated red data D_{RG}, a compensated green data D_{GG} and a compensated blue data D_{BG}. In addition, the gamma compensation in gamma compensating section 55_1 to gamma compensating section 55_3 includes the first compensation and second compensation, and further includes a second slight compensation caused by differences among red, green and blue not fully compensated by a gamma rough compensation (described later) common to red, green and blue in the second gamma compensation.

The gradation power supply circuit 52, as shown in Fig. 12, is provided with resistor 56_1 to resistor 56_{19} lengthwise connected between reference voltage V_{REF} and ground and voltage follower 57_1 to voltage follower 57_{17}, each of an input terminal is connected to a connection point of the adjacent resistor. The gradation power supply circuit 52 applies buffer to gradation voltage V_0 to gradation voltage V_{17} set for the second gamma rough compensation and supplies them to the data electrode driving

circuit 53.

The data electrode driving circuit 53, as shown in Fig. 12, is mainly provided with a MPX 58, a DAC 59 of eight bits and voltage follower 60_1 to voltage follower 60_{384}. In addition, in a real data electrode driving circuit, a shift register, a data register, a latch, a level shifter and a like are provided at a front step of the DAC, however, since there are no direct relationships between the features of the present invention and these elements and operations, the explanations thereof are omitted.

The MPX 58 switches the group of gradation voltage V_0 to gradation voltage V_8 and the group of gradation voltage V_9 to gradation voltage V_{17} among gradation voltage V_0 to gradation voltage V_{17} supplied from the gradation power supply circuit 52 based on the polarity inverting pulse POL supplied from the controlling circuit 51 and supplies it to the DAC 59. The DAC 59 applies the second gamma rough compensation to a compensated red data D_{RG} of eight bits, a compensated green data D_{GG} of eight bits and a compensated blue data D_{BG} of eight bits based on the group of gradation voltage V_0 to gradation voltage V_8 and the group of gradation voltage V_9 to gradation voltage V_{17} supplied from the MPX 58, converts these data into an analog data red signal, an analog data green signal and an analog data blue signal and supplies these signals to corresponding voltage follower 60_1 to corresponding voltage follower 60_{384}. The voltage follower 60_1 to the voltage follower 60_{384} apply buffer to the data red signal, the data green signal and the data blue signal supplied from the DAC 59 and apply these signals to the color liquid crystal display 1.

In addition, the gamma compensation in the DAC 59 is the

second gamma rough compensation common to red, green and blue in the second gamma compensation. As the second gamma rough compensation common to red, green and blue, for example, when the color liquid crystal display 1 has the V-T characteristic shown in Fig. 22 (curve a to curve c), the V-T characteristic curve obtained by averaging curve a to curve c is assumed, gradation voltage V_0 to gradation voltage V_{17} are set so that the second gamma rough compensation suitable to the assumed V-T characteristic curve is applied to the compensated red data D_{RG}, the compensated green data D_{GG} and the compensated blue data D_{BG}. In this case, the gamma slight compensation is applied to differences between the assumed V-T characteristic curve and curve a to curve c in gamma compensating section 55_1 to gamma compensating section 55_3.

Here, Fig. 13 shows an example of a relationship between the compensated red data D_{RG} of eight bits, the compensated green data D_{GG} of eight bits and the compensated blue data D_{BG} of eight bits (indicated by hexadecimal number (HEX)) and gradation voltage V_0 to gradation voltage V_8 and gradation voltage V_9 to gradation voltage V_{17}. As understood from Fig. 13, in order to apply the second gamma rough compensation to the compensated red data D_{RG}, the compensated green data D_{GG} and the compensated blue data D_{BG}, the group of gradation voltage V_0 to gradation voltage V_8 or gradation voltage V_9 to gradation voltage V_{17} which have nonlinear voltage values for the compensated red data D_{RG}, the compensated green data D_{GG} and the compensated blue data D_{BG} is supplied to the DAC 59.

Next, explanations will be given of operations in the controlling circuit 51, the gradation power supply circuit 52 and the data electrode driving circuit 53 which are features of the

present invention in the operations of the driving circuit for the color liquid crystal display 1.

First, the controlling circuit 51 independently applies the first gamma compensation and the second gamma slight compensation to the red data D_R of eight bits, the green data D_G of eight bits and the blue data D_B of eight bits supplied from the outside by an operational process to give a gradient to these data, and then each of compensation results are supplied to the data electrode driving circuit 53 as the compensated red data D_{RG}, the compensated green data D_{GG} and the compensated blue data D_{BG}. The gradation power supply circuit 52 applies buffer to gradation voltage V_0 to gradation voltage V_{17} set for the second gamma rough compensation and supplies them to the data electrode driving circuit 53.

Accordingly, the data electrode driving circuit 53 applies the second gamma rough compensation to the compensated red data D_{RG} of eight bits, the compensated green data D_{GG} of eight bits and the compensated blue data D_{BG} of eight bits supplied from the controlling circuit 51 based on the group of gradation voltage V_0 to gradation voltage V_8 or the group of gradation voltage V_9 to gradation voltage V_{17}, analog-converts these data into a data red signal, a data green signal and a data blue signal, and then applies buffer to these data so as to apply them to corresponding electrodes.

As above described, since the controlling circuit 51 executes the first gamma compensation and the second gamma slight compensation according to the fourth embodiment and the data electrode driving circuit 53 executes the second gamma rough compensation, two MPXs and two DACs can be reduced compared with

the third embodiment and effects approximately similar to the third embodiment can be obtained and a circuit scale can be reduced.

Fifth Embodiment

Next, explanations will be given of the fifth embodiment of the present invention.

Figure 14 is a block diagram showing an electrical configuration of a driving circuit of a digital circuit configuration for the color liquid crystal display 1 according to the fifth embodiment of the present invention. In Fig. 14, same numerals are given to corresponding parts in Fig. 11 and explanations thereof are omitted. The driving circuit for the color liquid crystal display 1 shown in Fig. 14 is provided with a controlling circuit 61 and the data electrode driving circuit 62 instead of the controlling circuit 51, the gradation power supply circuit 52 and the data electrode drive circuit 53 in Fig. 11.

The controlling circuit 61, for example, is an ASIC, and, as shown in Fig. 15, is mainly provided with a controlling section 63 and ROM 64_1 to ROM 55_3. The controlling section 61 generates a horizontal scanning pulse P_H, a vertical scanning pulse P_V and a polarity inverting pulse POL for alternatively driving the color liquid crystal display 1 and supplies them to the data electrode driving circuit 62 and the scanning electrode driving circuit 14 and supplies a control signal S_{CR}, a control signal S_{CG} and a control signal S_{CB} for controlling ROM 64_1 to ROM 64_3.

The ROM 64_1 to the ROM 64_3 are look-up tables , in order to

give a gradient to data by applying gamma compensation independently to red data D_R of eight bits, green data D_G of eight bits and blue data D_B of eight bits supplied from outside, previously memorized compensated red data D_{RG} of ten bits, compensated green data D_{GG} of ten bits and compensated blue data D_{BG} of ten bits which are respective compensated results and, when the red data D_R of eight bits, the green data D_G of eight bits and the blue data D_B of eight bits and the control signal S_{CR}, the control signal S_{CG} and the control signal S_{CB} are supplied from the controlling section 63, reads the corresponding compensated red data D_{RG} of ten bits, the corresponding compensated green data D_{GG} of ten bits and the corresponding compensated blue data D_{BG} of ten bits using the red data D_R, the green data D_G and the blue data D_B as referring addresses and supplies them to the data electrode driving circuit 62. In addition, the gamma compensation in ROM 64_1 to ROM 64_3 includes the first gamma compensation and the second gamma compensation.

Here, Fig. 16 shows an example of a relationship between the red data D_R of eight bits stored in the ROM 64_1 and the compensated red data D_{RG} of ten bits. Not shown, however, ROM 64_2 and ROM 64_3 also memorize the green data D_G, the compensated green data D_{GG} of ten bits corresponding to the blue data D_B and the compensated blue data D_{BG} similarly to Fig. 16.

The data electrode driving circuit 62, as shown in Fig. 15, is mainly provided with a gradation voltage supply source 65, a MPX 66, a DAC 59 of 10 bits and voltage follower 68_1 to voltage follower 68_{384}. In addition, in the real data electrode driving circuit, a shift register, a data register, a latch, a level shifter and a like are provided at a front step of a DAC, however,

since there are no direct relationships between the features of the present invention and these elements and operations, the explanations thereof are omitted.

The gradation voltage supply source 65 is provided with resistor 69_1 to resistor 69_5 lengthwise connected between a reference voltage V_{REF} and a ground and supplies a gradation voltage V_0, a gradation voltage V_8 a gradation voltage V9 and a gradation voltage V_{17} for converting the compensated red data D_{RG} of ten bits, the compensated green data D_{GG} of ten bits and the compensated blue data D_{BG} of ten bits generating at connection points of adjacent resistors into an analog red signal, an analog green signal and an analog blue signal to the MPX 66.

The MPX 66 switches the group of the gradation voltage V_0 and the gradation voltage V_8 and the group of the gradation voltage V_9 and the gradation voltage V_{17} among the gradation voltage V_0, the gradation voltage V_8, the gradation voltage V_9 and the gradation voltage V_{17} supplied from the gradation voltage supply source 65 based on the polarity inverting pulse POL supplied from the controlling circuit 61 and supplies it to DAC 67.

The DAC 67 converts the compensated red data D_{RG} of ten bits, the compensated green data D_{GG} of ten bits and the compensated blue data D_{BG} of ten bits into an analog red signal, an analog green signal and an analog blue signal based on the group of gradation voltage V_0 and the gradation voltage V_8 and the group of gradation voltage V_9 and the gradation voltage V_{17} supplied from the MPX 66 and supplies these signals to corresponding voltage follower 60_1 to corresponding voltage follower 60_{384}. The voltage follower 60_1 to voltage follower 60_{384} applies buffer to the data red signal, the data green signal and the data blue signal supplied

from the DAC 66 and apply these signals to the color liquid crystal display 1.

Here, Fig. 17 shows an example of a relationship between the compensated red data D_{RG} of ten bits, the compensated green data D_{GG} of ten bits and the compensated blue data D_{BG} of ten bits (indicated by hexadecimal number (HEX)) and gradation voltage V_0 to gradation voltage V_8 and gradation voltage V_9 to gradation voltage V_{17}. As understood from Fig. 17, the group of gradation voltage V_0 to gradation voltage V_8 or the group of gradation voltage V_9 to gradation voltage V_{17} which have nonlinear data values for the compensated red data D_{RG}, the compensated green data D_{GG} and the compensated blue data D_{BG} is supplied to the DAC 67.

Next, explanations will be given of operations in the controlling circuit 61 and the data electrode driving circuit 62 which are features of the present invention in the operations of the driving circuit for the color liquid crystal display 1.

First, the controlling section 63 in the controlling circuit 61 supplies the control signal S_{CR}, the control signal S_{CG} and the control signal S_{CB}, reads the compensated red data D_{RG}, the compensated green data D_{GG} and the compensated blue data D_{BG} of ten bits using the red data D_R of eight bits, the green data D_G of eight bits and the blue data D_B of eight bits supplied from the outside as referring addresses and supplies them to the data electrode driving circuit 62.

Accordingly, the data electrode driving circuit 62 analog-converts the compensated red data D_{RG} of ten bits, the compensated green data D_{GG} of ten bits and the compensated blue data D_{BG} of ten bits supplied from the controlling circuit 61 based on the group of the gradation voltage V_0 and the gradation voltage

V_8 or the group of the gradation voltage V_9 and the gradation voltage V_{17} into a data red signal, a data green signal and a data blue signal, and then applies buffer to these data so as to apply them to corresponding electrodes.

As above described, since the controlling circuit 61 executes the first gamma compensation and the second gamma compensation according to the fifth embodiment and the gradation power supply circuit 52 can be omitted compared with the fourth embodiment and effects approximately similar to the fourth embodiment can be obtained and a circuit scale can be reduced.

Also, according to fifth embodiment, only the compensated red data D_{RG}, the compensated green data D_{GG} and the compensated blue data read from ROM 64_1 to ROM 64_3, therefore, it is possible to execute gamma compensation at higher speed than the gamma compensation using the operational process as described in the fourth embodiment.

It is apparent that the present invention is not limited to the above embodiments but may be changed and modified without departing from the scope and spirit of the invention.

For example, in each of the above embodiments, the present invention is applied to a color liquid crystal display 1 of a normally white type, however, the present invention is not limited to this and may be applied to a color liquid crystal display of a normally black type in which a transmittance is low in a state that no voltage is applied. In this case, for example, in the third embodiment, not Fig. 10 but Fig. 18 shows a relationship between the red data D_R of eight bits supplied to the DAC 47_1 and the group of red gradation voltage V_{R0} to red gradation voltage V_{R8} and the group of red gradation voltage V_{R9} to red gradation voltage V_{R17}.

In another embodiment, the reference voltage and the gradation voltage, storage contents in ROM 64_1 to ROM 64_3 or a like may be changed so as to be suitable to the color liquid crystal display of the normally black type.

Also, in the above embodiments, the present invention is applied to the color liquid crystal display 1 of the active matrix driving type using TFT as a switch element, however, the present invention is not limited to this and may be applied any color liquid crystal display having any configuration and any function.

Also, the first gamma compensation and the second gamma slight compensation are applied by the operation process in the fourth embodiment and the first gamma compensation and the second gamma compensation are applied by reading data from the ROMs in the fifth embodiment, however, the present invention is not limited to this.

For example, in the fourth embodiment, the first gamma compensation and the second gamma slight compensation may be applied by reading data from a ROM and in the fifth embodiment, the first gamma compensation and the second gamma compensation may be applied by an operation process.

Also, Japanese Patent Application Laid-open Hei 10-313416 discloses that, concerning the first gamma compensation and the second gamma compensation, in the gamma characteristic of the color liquid crystal display 1, a gamma compensation may be applied to a curve part by reading data from a ROM, a RAM and a like and a gamma compensation may be applied to a linear part by an operation process.

Also, in the second embodiment, concerning the driving circuit of the analog configuration, the gamma compensation is

applied using the common reference voltage for the video red signal S_{RC}, the video green signal S_{GC} and the video green signal S_{BC} corresponding no difference area in each of the red V-T characteristic, the green V-T characteristic and the blue V-T characteristic of the color liquid crystal display 1, and therefore, circuit scale can be reduced. It is also possible to use this technique for a driving circuit of a digital circuit configuration.

For example, in the gradation power supply circuit 42 shown in Fig. 9, since only one gradation voltage may be generated concerning a same voltage value in among red gradation voltage V_{R0} to red gradation voltage V_{R17}, green gradation voltage V_{G0} to green gradation voltage V_{G17} and blue gradation voltage V_{B0} to blue gradation voltage V_{B17}, scale of the DAC 44 and number of voltage followers 45 for generating two other gradation voltage can be reduced.

Also, in each of the above-mentioned embodiments, the first gamma compensation is that a gamma compensation is applied to give a luminance characteristic of a reproduced image to a luminance of an input image, however, in addition to the gamma compensation suitable to the gamma characteristic of the CRT display (gamma is approximately 2.2), a gamma compensation different from the gamma characteristic of the CRT display and suitable another gamma characteristic may be applied. For example, when various commodities are sold via a television broadcast or an internet, the first gamma compensation is applied so as to match a color and a design of a real commodity with those displayed on the liquid crystal display.

Furthermore, in each of the above-mentioned embodiments, the

first gamma compensation always is applied, however, only the second gamma compensation may be applied.